Visualizing Flow Data in Unity Virtual Reality

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Introduction

Data analysis is central to any type of research In aerospace, visualizing flow data has been traditionally done with figures and charts. However, these methods have limitations such as being confined to two dimensions and offering relatively little interactivity with the data. That is why this project utilized Virtual Reality (VR) technology to better display the nuances of flow data. The project specifically tested the limits of the Unity game engine to display and process large data sets while providing a smooth user experience on a smartphone VR device.

Objective, Methods and Impact of Our Research

The ability to better visualize flow fields would be extremely useful for researchers who want to understand their data more clearly or for the general public to get a better understanding of aerodynamics. When we started this project, we were really unsure where it would take us.

There was little prior research on this topic that we could reference, so we were not sure if Unity could even handle this much data. But, with much effort, we were able to demonstrate that Unity can handle this data, and it can display the data in VR quite well.

The hardware that was used for this project included an Xbox Controller, Google Cardboard, and an Android Smartphone. The Unity toolset can be a powerful tool for scientific visualization given the low cost and low barrier of entry.

Hardware Used

Skills Learned

- **Coding / Programming**
  - In order to better understand how we were going to manipulate the data I learned and utilized **MATLAB** for its powerful data processing ability
  - **C#** was necessary for programming scripts in Unity which controlled player input, reading of the data from a CSV (Excel) file, and plotting it in the scene. I learned how to use object oriented programming (OOP), arrays, lists, dictionaries, and floating point math. I had limited experience with coding, so I appreciated my mentor assisting me with learning this new language.
- **Unity**
  - Beyond the scripting aspect, I had to learn how to use Unity itself. Notable parts include:
  - The **New Input Manager** which was gave us quite a lot of trouble when we tried to connect an Xbox controller via Bluetooth to the phone.
  - Manipulating the scene and color of objects using the **inspector window**
  - Installing the **Google Cardboard package** to build the project on a smartphone VR
- **Math**
  - Learned how to rotate objects using Quaternions, which do not gimbal lock like Euler Rotations
  - Vector math was used to plot objects in the scene
  - Learned how to use **interpolation equations** to draw pathlines and streamlines. Essentially, this is the line a particle would follow based on the surrounding vectors

$$c_0 = \frac{1}{(x_1 - x_2)(y_1 - y_2)}\left(f_4 \cdot x_1 y_1 - f_3 \cdot x_1 y_2 - f_2 \cdot x_2 y_1 + f_1 \cdot x_2 y_2\right)$$
$$c_1 = \frac{1}{(x_1 - x_2)(y_1 - y_2)}\left(f_4 \cdot y_1 - f_3 \cdot y_2 - f_2 \cdot y_1 + f_1 \cdot y_2\right)$$
$$c_2 = \frac{1}{(x_1 - x_2)(y_1 - y_2)}\left(f_4 \cdot x_1 - f_3 \cdot x_1 - f_2 \cdot x_2 + f_1 \cdot x_2\right)$$
$$c_3 = \frac{1}{(x_1 - x_2)(y_1 - y_2)}\left(f_4 - f_3 - f_2 + f_1\right)$$

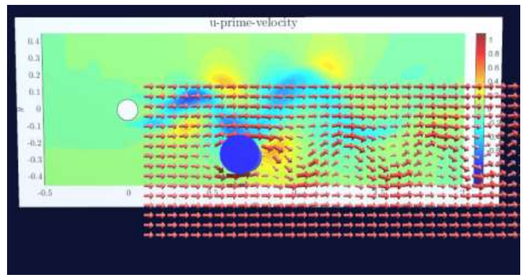
Example of interpolation equations used

Results/Conclusion

We were able to accomplish our goal of visualizing flow data in the Unity engine, and we even went beyond.

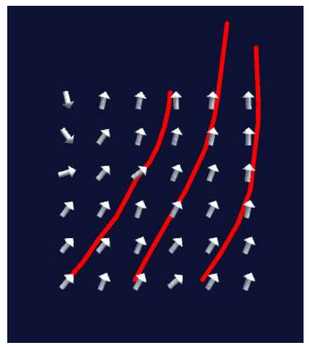
We have two scenes present in our final result:

Scene 1: An animated flow field that depicts a “Von Karman Vortex Street” where a cylinder disrupts a steady flow. It features over 1000 vectors that update every 0.1 seconds. The vectors change color and size depending on their magnitude (darker and larger for a greater magnitude). A screen in the background depicts a graph of the data in MATLAB.



Scene 1
(Dataset provided by Tobias Gunther, Markus Gross and Holger Theisel)

Scene 2: A group of 36 static points are present, and the plotter draws pathlines over time, interpolating the velocity between each point



Scene 2

How SHINE Relates to My STEM Coursework

By being a part of this project, I have reinforced my love for aerospace engineering, and I feel much more confident about majoring in this subject.
The ability to do research like this was an amazing experience for me. It far exceeded the opportunities available to a normal high schooler.
I hope to continue to do research like this when I attend college. I found that I really enjoyed it, even though I was not entirely familiar with the subject matter.

Next Steps

In the future, I would love to continue to fine tune this project.
Since the “hard part” (reading of the data) is now implemented, more emphasis can be put on the player experience and user interface (UI).
From here, there are many different directions that the experience could take. I would love to make the scene look more like a wind tunnel, which would provide some immersion, and include a loading screen and main menu.
If COVID-19 precautions permit, we hope to have a demonstration available.

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